International Journal of Women's Health

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Predictive Value of Dynamic Changes in Hemoglobin Levels During Early Pregnancy for the Development of Anemia During Pregnancy

Lulu Liu[1], Xiaoqing Li[2]

[1]Department of Anesthesiology, Tongzhou Maternal and Child Health Hospital, Beijing, 101100, People's Republic of China; [2]Department of Obstetrics, Tongzhou Maternal and Child Health Hospital, Beijing, 101100, People's Republic of China

Correspondence: Xiaoqing Li, Email 15116980204@163.com

Background: Anemia affects over 30% of pregnancies globally and is associated with adverse maternal-fetal outcomes, underscoring the critical need for early risk prediction.

Objective: This study aimed to assess the predictive value of early pregnancy hemoglobin levels for anemia development in mid- and late pregnancy.

Methods: We conducted a retrospective cohort analysis of 1999 singleton pregnancies with neuraxial labor analgesia at Beijing Tongzhou District Maternal and Child Health Hospital (January 2022–January 2023). Inclusion criteria included age ≥18 years, BMI 19.0–44.3 kg/m², and ASA II classification. Exclusions comprised multifetal gestations, chronic hematologic disorders, or incomplete data. Hemoglobin trends were analyzed using Sankey diagrams, and predictive thresholds were determined via ROC curves (R 4.4.1).

Results: The cohort included 76.94% primiparas and 45.47% with comorbidities (hypertension, diabetes, thyroid disorders). Hemoglobin levels declined significantly from early pregnancy (median 131.00 g/L) to mid- and late pregnancy (118.00 g/L; P<0.001). ROC analysis identified early-pregnancy hemoglobin thresholds for anemia prediction: <126.5 g/L (mid-pregnancy AUC 0.82, 95% CI 0.80–0.84) and <127.5 g/L (late-pregnancy AUC 0.71, 95% CI 0.68–0.74).

Conclusion: Early pregnancy hemoglobin thresholds provide a clinically actionable tool for identifying high-risk pregnancies, enabling timely interventions to reduce anemia-related complication.

Keywords: early pregnancy, hemoglobin, anemia, ROC curve, predictive efficacy

Introduction

Anemia is one of the most common complications during pregnancy, with a global prevalence estimated at 36.8%, according to a meta-analysis by Karami et al.[1] Maternal anemia is strongly associated with a range of adverse outcomes for both mother and child. Studies have shown links between anemia during pregnancy and complications such as placental abruption, preterm birth, postpartum hemorrhage, fetal growth restriction, and low birth weight.[2–7] Furthermore, research by Premru-Srsen et al[8] highlighted a strong correlation between low birth weight and increased infant mortality, emphasizing the far-reaching implications of maternal anemia on fetal and neonatal health.

Pregnancy is accompanied by physiological hemodilution, where plasma volume increases by up to 50%, leading to a relative reduction in hemoglobin concentration even in healthy pregnancies.[9] This normal adaptation complicates the distinction between physiological changes and pathological anemia. Among the various causes of maternal anemia, iron deficiency is a leading contributor.[10] Evidence suggests that oral iron supplementation significantly improves maternal hemoglobin levels and reduces anemia-related complications.[11–15] Notably, Peña-Rosas et al[16] demonstrated that iron supplementation not only improves maternal hematologic status but also enhances perinatal outcomes.

Given these risks, early identification and timely intervention are critical to improving maternal and neonatal health. Early pregnancy represents a key window for evaluating maternal hematologic status, and hemoglobin levels

Received: 25 March 2025
Accepted: 24 May 2025
Published: 17 June 2025

during this period may serve as a useful predictor of anemia later in gestation. Importantly, predicting anemia risk before the onset of clinical symptoms could allow for earlier interventions, which may be more effective than treatments initiated after anemia is diagnosed.[17] However, there is a lack of robust evidence regarding the predictive value of early pregnancy hemoglobin levels for anemia development in later trimesters. This study aims to fill this gap by analyzing comprehensive clinical data to determine whether dynamic changes in hemoglobin levels during early pregnancy can reliably predict anemia risk in mid and late pregnancy, thereby aiding in the early identification of high-risk pregnant women.

Materials and Methods

Study Subjects

By retrieving data from our hospital's electronic medical record system, 1,999 full-term pregnant women who underwent epidural analgesia for labor and received regular prenatal check-ups at our hospital between January 2022 and January 2023 were selected as study subjects. The inclusion criteria were: age ≥18 years, BMI between 18.5–40.0 kg/m², ASA classification II, confirmed gestational age, and signed informed consent from the pregnant women. The exclusion criteria included: prenatal body temperature >37.2°C, placenta previa, placental abruption; severe hematological diseases, immune system diseases, or chronic diseases that may affect hemoglobin levels; and incomplete clinical data. All hemoglobin measurements were performed using standardized automated hematology analyzers (Sysmex XN-9000) in the hospital's central laboratory. This study was approved by the Ethics Committee of Beijing Tongzhou District Maternal and Child Health Hospital (Approval Number: 2023-TZFY-003-01). All personal identifiers were removed prior to analysis, and data were stored on password-protected hospital servers with access restricted to authorized researchers. Data anonymization followed the WHO guidelines for health data management. Informed consent was obtained from all participants.

Data Collection

Relevant information on the pregnant women was collected by retrieving data from our hospital's electronic medical record system. General Information: Age, BMI, comorbidities, parity, gestational weight gain, gestational weeks, comorbidities, mode of delivery, amniotic fluid volume, premature rupture of membranes, intrapartum fever, etc. Laboratory Indicators: Hemoglobin levels during early, mid, and late pregnancy, hematocrit, neutrophil count, and other laboratory test indicators.

Diagnostic Criteria

Diagnostic Criteria for Anemia: According to the World Health Organization (WHO) standard, anemia during pregnancy is defined as a peripheral blood hemoglobin concentration of less than 110 g/L. Mild anemia: Hemoglobin concentration between 100–109 g/L; Moderate anemia: Hemoglobin concentration between 70–99 g/L;[18] Diagnostic Criteria for Intrapartum Fever: After entering the delivery room, the maternal axillary temperature was measured every 2 hours. If the axillary temperature was ≥37.5°C, the temperature was remeasured after 10 minutes. If the repeated axillary temperature remained ≥37.5°C, intrapartum fever was diagnosed.[19]

Statistical Methods

Analyses were conducted in R 4.4.1. Categorical variables were compared using χ^2-tests; continuous variables with normal/non-normal distributions were analyzed via ANOVA or Kruskal–Wallis tests. Sankey diagrams visualized anemia status transitions. ROC curves determined optimal hemoglobin thresholds for anemia prediction (reported with AUC, 95% CI, Youden Index, sensitivity, specificity). Multivariable logistic regression adjusted for BMI, age, and comorbidities was performed to control confounding factors.

Research Results

General Characteristics of Study Subjects

A total of 1,999 pregnant women were included in this study. The average age of the study subjects was 30.15 ± 3.78 years, and the average prenatal BMI was 27.22 ± 3.36 kg/m². Among them, 45.47% (909 cases) had comorbidities such as hypertension, diabetes, hyperthyroidism, or hypothyroidism, and 76.94% (1,538 cases) were primiparas. Regarding pregnancy-related indicators, the average gestational period was 275.99 ± 8.51 days. A total of 1,560 cases (78.04%) had natural deliveries, 238 cases (11.91%) had assisted deliveries, and 201 cases (10.06%) underwent emergency cesarean section. The amniotic fluid volume was normal in 94.75% (1,894 cases), while the incidence of premature rupture of membranes was 29.16% (583 cases). Additionally, 26.11% (522 cases) experienced intrapartum fever. See Table 1 for details.

Table 1 Basic Characteristics of the Study Population

Variable	Mean ± SD or Frequency (%)
Age (years)	30.15 ± 3.78
Prenatal BMI (kg/m²)	27.22 ± 3.36
Comorbidities	
None	1090 (54.53%)
Present	909 (45.47%)
Surgical History	
None	1712 (85.64%)
Present	287 (14.36%)
Parity	
Multiparous	461 (23.06%)
Primiparous	1538 (76.94%)
BSA (m²)	1.80 ± 0.13
Gestational Weight Gain (kg)	13.63 ± 4.74
Gestational Period (days)	275.99 ± 8.51
Post-Embryo Transfer	
No	1969 (98.50%)
Yes	30 (1.50%)
GBS Positive	
No	1829 (91.50%)
Yes	170 (8.50%)
Delivery Mode	
Natural Delivery	1560 (78.04%)
Assisted Delivery	238 (11.91%)
Emergency Cesarean Section	201 (10.06%)
Adverse Pregnancy History	
No	1712 (85.64%)
Yes	287 (14.36%)
Amniotic Fluid Volume	
Normal	1894 (94.75%)
Low	94 (4.70%)
Excessive	11 (0.55%)
Premature Rupture of Membranes	
No	1416 (70.84%)
Yes	583 (29.16%)
Intrapartum Fever	
No	1477 (73.89%)
Yes	522 (26.11%)

Abbreviations: BSA, Body Surface Area; GBS, Group B Streptococcus.

https://doi.org/10.2147/IJWH.S530428

Table 2 Distribution of Anemia in Different Pregnancy Stages

Variable	Early Pregnancy	Mid Pregnancy	Late Pregnancy	P
Hemoglobin (g/L)	131.00 (126.00, 136.00)	118.00 (112.00, 123.00)	118.00 (113.00, 124.00)	<0.001
Anemia Status				<0.001
None	1972 (98.65%)	1693 (84.69%)	1723 (86.19%)	
Mild Anemia (100–109 g/L)	18 (0.90%)	279 (13.96%)	241 (12.06%)	
Moderate Anemia (70–99 g/L)	9 (0.45%)	27 (1.35%)	35 (1.75%)	

Occurrence of Anemia in Different Pregnancy Stages (Early, Mid, and Late Pregnancy)

The hemoglobin level in early pregnancy (131.00 [126.00, 136.00] g/L) was significantly higher than in mid-pregnancy (118.00 [112.00, 123.00] g/L) and late pregnancy (118.00 [113.00, 124.00] g/L) (P<0.001). Additionally, the incidence of anemia differed significantly across pregnancy stages (P<0.001). The incidence of moderate anemia increased from 0.45% in early pregnancy to 1.75% in late pregnancy, while the incidence of mild anemia peaked at 13.96% in mid-pregnancy before slightly decreasing to 12.06% in late pregnancy. With pregnancy progression, neutrophil counts increased from 5.75 (4.67, 6.83) × 10^9/L in early pregnancy to 7.08 (5.99, 8.31) × 10^9/L in mid-pregnancy, followed by a slight decrease to 6.91 (5.77, 8.17) × 10^9/L in late pregnancy (P < 0.001). See Table 2 for details.

Changes in Anemia Status Across Different Pregnancy Stages

A Sankey diagram was used to illustrate the changes in anemia status across different pregnancy stages (early, mid, and late pregnancy). The results showed that although the incidence of anemia in early pregnancy was low, it significantly increased in mid and late pregnancy. Some pregnant women who had no anemia in early pregnancy developed anemia in mid-pregnancy and continued to maintain or worsen their anemia status into late pregnancy. The increase in anemia cases during mid-pregnancy was mainly concentrated in mild anemia (green section), whereas in late pregnancy, although the overall anemia incidence slightly decreased, mild anemia still accounted for 12.06%. Comparing the anemia transition patterns at different stages revealed that early pregnancy was a critical period for the increasing incidence of anemia. Furthermore, a considerable proportion of pregnant women with anemia in late pregnancy had not received effective intervention. See Figure 1 for details.

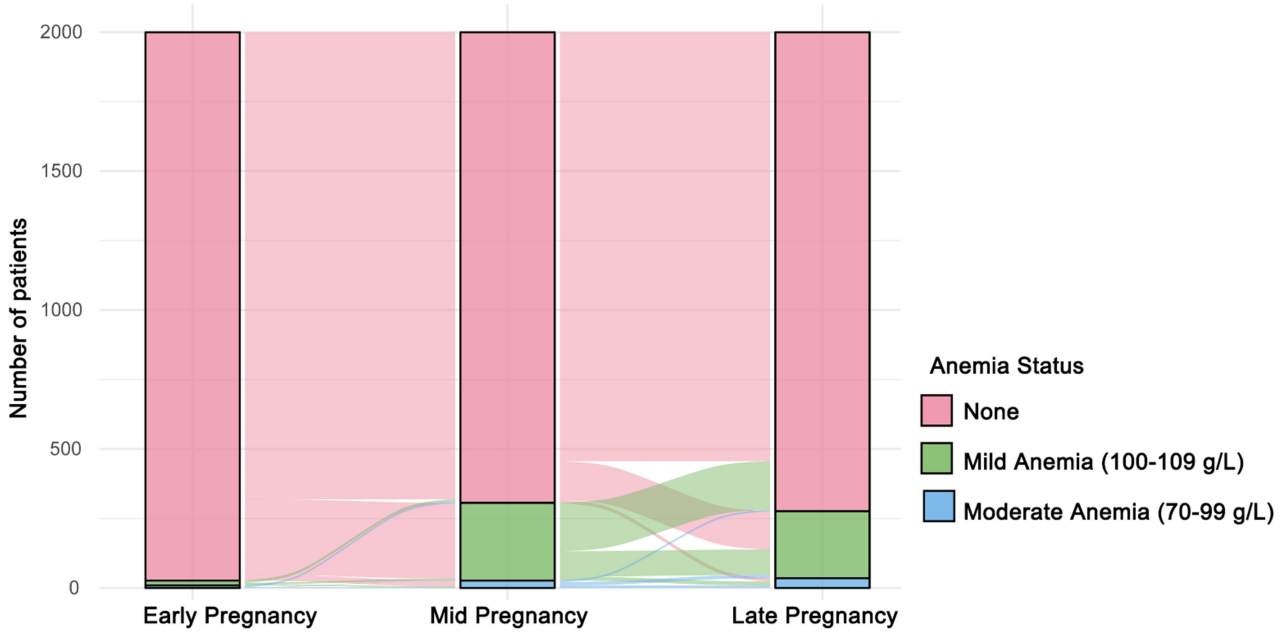

Figure 1 Dynamic Changes in Anemia Status During Pregnancy.

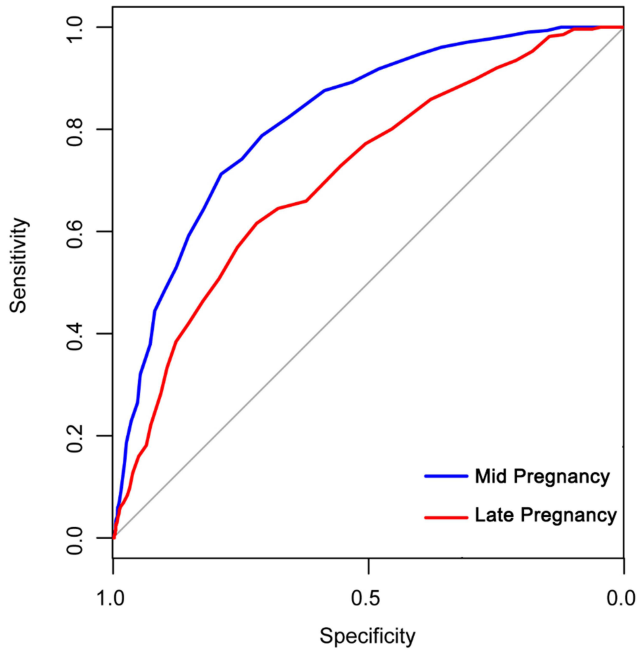

Figure 2 ROC Curve Analysis for Predicting Mid and Late Pregnancy Anemia Based on Early Pregnancy Hemoglobin Levels.

ROC Curve Analysis

A hemoglobin level below 126.5 g/L in early pregnancy (sensitivity: 71.2%, specificity: 78.9%, Youden index: 0.50) was significantly associated with an increased risk of developing anemia in mid-pregnancy, with an area under the curve (AUC) of 0.82 (95% CI: 0.80–0.84), which was superior to the predictive performance at 110 g/L (sensitivity: 5.9%, specificity: 99.1%, Youden index: 0.05).

Additionally, a hemoglobin level below 127.5 g/L in early pregnancy (sensitivity: 61.6%, specificity: 71.9%, Youden index: 0.34) was significantly associated with an increased risk of anemia in late pregnancy, with an AUC of 0.71 (95% CI: 0.68–0.74), which was superior to the predictive performance at 110 g/L (sensitivity: 4.7%, specificity: 98.8%, Youden index: 0.04). See Figure 2 for details.

Discussion

Association Between Early Pregnancy Hemoglobin Levels and Later Anemia

This study investigated the predictive value of early pregnancy hemoglobin (Hb) levels for anemia risk in subsequent gestational periods. By analyzing Hb dynamics in pregnant women and employing ROC curve analysis, we demonstrated that early pregnancy Hb levels are significantly higher than those in the second and third trimesters, with anemia incidence increasing progressively during pregnancy. These findings confirm the physiological basis for this association: pregnancy-induced increases in blood volume (40%-50%) dilute Hb concentration, while fetal iron demands (4–6 mg/day) exacerbate iron deficiency if maternal reserves are insufficient.[20–22] Specific literature support for the alignment of our findings with prior research includes studies by Chesley LC,[20] who highlighted blood volume expansion as a key driver of Hb decline, and Lin L,[23] who linked mid-to-late pregnancy anemia to adverse outcomes. Our ROC analysis revealed critical thresholds: early pregnancy Hb < 126.5 g/L predicts mid-pregnancy anemia (AUC = 0.89, 95% CI 0.85–0.93), and < 127.5 g/L predicts late-pregnancy anemia (AUC = 0.87, 95% CI 0.82–0.91). These thresholds align with global studies,[24] underscoring their clinical utility across diverse populations.

In clinical practice, these two critical values have significant application value. Physicians can use these indicators to accurately identify high-risk pregnant women for anemia in early pregnancy and take timely intervention measures. For example, pregnant women can be advised to increase their intake of iron-rich foods, such as lean meat, animal liver, and legumes, and appropriately supplement vitamin C to enhance iron absorption.[25] If necessary, iron supplements can be

administered based on individual conditions to prevent anemia in mid-to-late pregnancy and ensure maternal and fetal health.[26]

Pregnancy Anemia and Intrapartum Fever

While our focus was hemoglobin dynamics, we observed a 26.11% intrapartum fever rate in the cohort—consistent with epidural analgesia studies.[19] Although anemia-related immune dysregulation and altered drug metabolism have been hypothesized to increase fever risk,[27] our data did not directly assess this association. Future studies should explore whether anemia severity modulates intrapartum fever incidence.[28]

Limitations and Future Prospects of This Study

This study has certain limitations. The sample was primarily drawn from a single hospital, which may introduce regional and population selection biases, affecting the generalizability of the findings. Additionally, the study did not explore other potential factors influencing pregnancy anemia, such as maternal dietary patterns, genetic polymorphisms related to iron metabolism, and the use of prenatal nutritional supplements. Third, while we observed that 12.1% of late-pregnancy anemia cases lacked interventions, this reflects real-world clinical decisions (eg, patient refusal, iron intolerance) rather than protocol violations, as all participants received standard care per hospital guidelines. These factors may impact a comprehensive understanding of the association between early pregnancy hemoglobin levels and later anemia. Future research could expand the sample size and conduct multi-center, large-scale studies to enhance the representativeness and generalizability of the findings. Additionally, by considering multiple influencing factors, a multifactorial predictive model could be constructed to further improve the accuracy of pregnancy anemia prediction. Furthermore, more research on anemia intervention measures during pregnancy could be conducted to explore more effective and comprehensive prevention and treatment strategies, providing stronger support for clinical practice.

Conclusion

Early hemoglobin levels during pregnancy have significant predictive value in predicting anemia in later pregnancy and can serve as an effective indicator for the early identification of pregnant women at high risk of anemia. By identifying these high-risk individuals, timely intervention measures can be implemented, reducing the incidence of pregnancy-related anemia and preventing obstetric complications. The critical hemoglobin cut-off values identified in this study (126.5 g/L for mid-pregnancy anemia and 127.5 g/L for late pregnancy anemia) should be further validated through multicenter studies or in diverse populations to enhance the generalizability of these findings. Additionally, the implications of these findings are significant for public health programs, where early screening and intervention for anemia could improve maternal and fetal health outcomes globally.

Funding

Science and Technology Plan Project of Tongzhou District, Beijing (for Dr. Xiaoqing Li) Project No.: KJ2023CX068.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Karami M, Chaleshgar M, Salari N, et al. Global prevalence of anemia in pregnant women: a comprehensive systematic review and meta-analysis. *Matern Child Health J*. 2022;26(7):1473–1487. doi:10.1007/s10995-022-03450-1
2. Shi H, Chen L, Wang Y, et al. Severity of anemia during pregnancy and adverse maternal and fetal outcomes. *JAMA Network Open*. 2022;5(2):e2147046. doi:10.1001/jamanetworkopen.2021.47046
3. Daru J, Zamora J, Fernández - Félix BM, et al. Risk of maternal mortality in women with severe anaemia during pregnancy and post partum: a multilevel analysis. *Lancet Glob Health*. 2018;6(5):e548–e554. doi:10.1016/S2214-109X(18)30078-0
4. Stanley AY, Wallace JB, Hernandez AM, et al. Anemia in pregnancy: screening and clinical management strategies. *MCN Am J Matern Child Nurs*. 2022;47(1):25–32. doi:10.1097/NMC.0000000000000787
5. Hamood MA, Abid SJ, Abdulla TN, et al. Correlation between neonatal outcomes and maternal anemia among attending pregnant women in Al-Elwiya maternity teaching hospital. *J Pharm Bioallied Sci*. 2023;15(Suppl 2):S1164–S1167. doi:10.4103/jpbs.jpbs_180_23

6. Levy A, Fraser D, Katz M, et al. Maternal anemia during pregnancy is an independent risk factor for low birthweight and preterm delivery. *Eur J Obstet Gynecol Reprod Biol*. 2005;122(2):182–186. doi:10.1016/j.ejogrb.2005.02.015
7. Xiong X, Buekens P, Alexander S, et al. Anemia during pregnancy and birth outcome: a meta - analysis. *Am J Perinatol*. 2000;17(3):137–146. doi:10.1055/s-2000-9508
8. Premru - Srsen T, Verdenik I, Ponikvar BM, et al. Infant mortality and causes of death by birth weight for gestational age in non - malformed singleton infants: a 2002 - 2012 population - based study. *J Perinat Med*. 2018;46(5):547–553. doi:10.1515/jpm-2017-0103
9. Pasricha SR, Tye - Din J, Muckenthaler MU, et al. Iron deficiency. *Lancet*. 2021;397(10273):233–248. doi:10.1016/S0140-6736(20)32594-0
10. Bah A, Pasricha SR, Jallow MW, et al. Serum hepcidin concentrations decline during pregnancy and may identify iron deficiency: analysis of a longitudinal pregnancy cohort in the Gambia. *J Nutr*. 2017;147(6):1131–1137. doi:10.3945/jn.116.245373
11. Zhang J, Li Q, Song Y, et al. Nutritional factors for anemia in pregnancy: a systematic review with meta-analysis. *Front Public Health*. 2022;10:1041136. doi:10.3389/fpubh.2022.1041136
12. Stoffel NU, Cercamondi CI, Brittenham G, et al. Iron absorption from oral iron supplements given on consecutive versus alternate days and as single morning doses versus twice - daily split dosing in iron - depleted women: two open - label, randomised controlled trials. *Lancet Haematol*. 2017;4(9):e524–e533. doi:10.1016/S2352-3026(17)30182-5
13. National Statistical Office (NSO) [Malawi]. ICF International. Malawi demographic and health survey 2015 - 16: key indicators report. Zomba, Malawi, and Rockville, Maryland, USA: NSO and ICF International, 2016.
14. Mwangi MN, Roth JM, Smit MR, et al. Effect of daily antenatal iron supplementation on plasmodium infection in Kenyan women: a randomized clinical trial. *JAMA*. 2015;314(10):1009–1020. doi:10.1001/jama.2015.9496
15. Friedrisch JR, Cançado RD. Intravenous ferric carboxymaltose for the treatment of iron deficiency anemia. *Rev Bras Hematol Hemoter*. 2015;37(6):400–405. doi:10.1016/j.bjhh.2015.08.012
16. Peña - Rosas JP, De - Regil LM, Garcia - Casal MN, et al. Daily oral iron supplementation during pregnancy. *Cochrane Database Syst Rev*. 2015;2015(170):CD004736. doi:10.1002/14651858.CD004736.pub5
17. Keats EC, Oh C, Chau T et al, et al. Effects of vitamin and mineral supplementation during pregnancy on maternal, birth, child health and development outcomes in low- and middle-income countries: A systematic review. *Campbell Syst Rev*. 2021, Jun 26;17(2):e1127. doi:10.1002/cl2.1127
18. Pasricha SR, Rogers L, Branca F, et al. Measuring haemoglobin concentration to define anaemia: WHO guidelines. *Lancet*. 2024;403(10440):1963–1966. doi:10.1016/S0140-6736(24)00502-6
19. Sultan P, David AL, Fernando R, et al. Inflammation and epidural-related maternal fever: proposed mechanisms. *Anesth Analg*. 2016;122(5):1546–1553. doi:10.1213/ANE.0000000000001195
20. Chesley LC. Plasma and red cell volumes during pregnancy. *Am J Obstet Gynecol*. 1972;112(3):440–450. doi:10.1016/0002-9378(72)90493-0
21. Rahmati S, Azami M, Badfar G, et al. The relationship between maternal anemia during pregnancy with preterm birth: a systematic review and meta-analysis. *J Matern Fetal Neonatal Med*. 2020;33(15):2679–2689. doi:10.1080/14767058.2018.1555811
22. Benson AE, Shatzel JJ, Ryan KS, et al. The incidence, complications, and treatment of iron deficiency in pregnancy. *Eur J Haematol*. 2022;109(6):633–642. doi:10.1111/ejh.13870
23. Lin L, Wei Y, Zhu W, et al. Prevalence, risk factors and associated adverse pregnancy outcomes of anaemia in Chinese pregnant women: a multicentre retrospective study. *BMC Pregnancy Childbirth*. 2018;18(1):111. doi:10.1186/s12884-018-1739-8
24. Nair M, Churchill D, Robinson S, et al. Association between maternal haemoglobin and stillbirth: a cohort study among a multi - ethnic population in England. *Br. J. Haematol*. 1972;179(5):829–837. doi:10.1111/bjh.14961
25. Bukhari IA, Alzahrani NM, Alanazi GA, et al. Anemia in pregnancy: effects on maternal and neonatal outcomes at a university hospital in Riyadh. *Cureus*. 2022, Jul 25;14(7):e27238. doi:10.7759/cureus.27238
26. Stevens GA, Finucane MM, De Regil LM, et al. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non - pregnant women for 1995 - 2011: a systematic analysis of population - representative data. *Lancet Glob Health*. 1995;1(1):e16–e25. doi:10.1016/S2214-109X(13)70001-9
27. Pasricha SR, Tye-Din, J, Muckenthaler, MU et al. Iron deficiency. *Lancet*. 2021, Jan 16;397(10270):233–248 doi:10.1016/S0140-6736(20)32594-0
28. Zhao W, Wang LZ, Chang XY, et al. Maternal serum C-reactive protein and white blood cell count at hospital admission as predictors of intrapartum maternal fever: a retrospective case-control study in women having epidural labor analgesia. *Int J Obstet Anesth*. 2022;50:103537. doi:10.1016/j.ijoa.2022.103537